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REPORT

ON THE

PURIFICATION AND UTILIZATION

OF THE

SEWAGE OF GLASGOW AND SUBURBS.

WITH APPENDICES.

ADDRESSED TO THE CHAIRMAN OF THE
COMMITTEE ON HEALTH.

BY

JOHN YOUNG,
INSPECTOR OF CLEANSING.

GLASGOW:
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1888.

EXTRACT MINUTE OF COMMITTEE ON HEALTH.

Glasgow, *28th November, 1888.*

MET THE COMMITTEE ON HEALTH.

Present—Bailies Thomson and M'Lennan.
Councillors Crawford (Chair), Bilsland, Bowman, Guthrie, M'Farlane, M'Kellar, M'Lean, Neil, Pettigrew, and Wm. Wilson.

Also present—Councillor Graham;
Along with the Medical Officer, Inspector of Cleansing, Sanitary Inspector, and the Master of Works.

The Chairman stated that he had called this Special Meeting for the purpose of submitting a letter addressed to him by the Inspector of Cleansing on the disposal of the Sewage of Glasgow. The communication was then read; and, after some discussion, it was unanimously agreed, in the meantime, that Mr. Young be thanked for his paper, and that it, with the appendices, be printed in pamphlet form, and a copy sent to each Member of Council, and others interested.

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REPORT.

To Bailie Crawford,
Chairman of the Committee on Health.

Dear Sir,

In carrying out the remit from my Committee to visit various towns in connection with "Cleansing" matters, I took the opportunity, as directed by you, of observing the methods of sewage purification in operation at the several places visited. In fact, I specially extended my route, in order to gain further information upon this kindred subject.

I may state, at the outset, that I have seen nothing at Birmingham, Nottingham, Croydon, Berlin, Paris, and other places visited, to cause me to alter my opinion, as some time ago expressed to you,—viz., that it is quite *practicable* to purify, and at the same time utilize the sewage of Glasgow by irrigating the plains of the Cart and Gryffe,—called in earlier times "Strathgryffe."

I may also explain that by irrigation I do not mean that the sewage is simply to flow *over* the land, but is to be filtered *through* it,—practically the process which has been termed "intermittent downward filtration."

While it may be supposed that my experience should have given me some knowledge on the subject of land irrigation, and while I have expressed the opinion that the sewage of Glasgow *can* be utilized and purified by this means, I know all methods of dealing with sewage are open to objection; and I have no wish to appear as the special pleader of any scheme. I simply wish to put into your hands the following remarks and particulars, to shew the lines on which my opinion is based, leaving you and your Committee to make use of them or not, as you think proper.

The proposals of Messrs. Bateman and Bazalgette in 1868, and of Sir John Hawkshaw in 1876, to convey the crude sewage of Glasgow to the Ayrshire coast, have led to nothing as yet. The result gained by these schemes was not even destruction, but simply the passing over of the sewage to another point, and to another authority, who might naturally object to it. The former scheme, it will be remembered, suggests the possibility of irrigating the sandy bluffs on the Ayrshire coast by again pumping the sewage to the necessary level near the outlet.

In 1877, the system of clarifying or purifying the sewage by chemical precipitation was recommended by the Deputation of the Town Council specially appointed to report on the subject; which Deputation I had the honour of accompanying. This recommendation in favour of chemical precipitation was made, and was received with considerable favour, in the belief (1) that by such a process the effluent water would not afterwards ferment, but would be fit to run into the river direct from the works; and (2) that the precipitated sludge could be deposited by barges in Loch Long.

Since then, however, we have seen that the system of precipitation in tanks by lime (which was the precipitant then specially pointed to) has had to be abandoned in some cases, and supplemented in others. Leicester, for instance, has, after a long trial, given it up in favour of irrigation; and Birmingham has supplemented it by irrigation. Paris also tried precipitation,—chiefly by sulphate of alumina,—but has abandoned it and adopted irrigation.

With regard to the sludge from precipitation works, it is now very doubtful if the depositing of this material in Loch Long would be permitted.

It is now very generally understood by those who have given attention to the question, that any really successful precipitation scheme must, at a reasonable cost, extract the most of the ammonia from the sewage, so as to give forth a satisfactory effluent; and further, that all the ammonia thus extracted must be fixed and retained in the sludge before there can be any hope of its being worth pressing or drying, as sludge without the ammonia cannot be otherwise than difficult and costly to get rid of.

It is also the general opinion of competent authorities on the subject, that the best effluent is obtained by filtering sewage through land; and experience has proved that, in order to obtain a good effluent, some such filtration, natural or artificial, is a necessary adjunct to any known chemical process.

The double process, however, of precipitation in tanks and filtration through land afterwards, is necessarily very expensive.

I have therefore been led to inquire whether it is practicable to purify the sewage of Glasgow by intermittent irrigation *alone*. This single process obviates altogether the sludge difficulty. Besides, irrigation carries on the face of it the obvious advantages of *utilizing* the manurial properties of the liquid refuse in raising increased food supplies, and of opening up a field for the employment of considerably more labour upon the land.

I am aware that Mr. Carrick, our highest authority on sewerage, many years ago suggested a tentative scheme of irrigating with the high-level sewage the flat lands on the north side of the river above Yoker. And since this paper was drafted, I have with pleasure observed in the appendix to the report of Messrs. Bateman and Bazelgette, that Mr. Gale, in 1865, submitted to the Hon. John Blackie, Jun., the then Lord Provost, a complete and well-digested scheme of irrigation upon the low lands of Paisley.

In considering this question of irrigation, we have now much better data to start with than we had even ten years ago; and, however valuable laboratory experiments may be, it seems to me we must consult experience before we can decide the matter satisfactorily.

The Birmingham Tame and Rea District Drainage Board still continue at Saltley to pass the whole, or very nearly the whole sewage of their drainage district through the lime process of precipitation in tanks, at a cost now reduced to

£10,422 per annum, including the trenching-in of the foul-smelling sludge. They found long ago, however, that the lime process of itself did not purify the sewage sufficiently to meet the requirements of the "Rivers' Pollution Act." Accordingly they gradually fell back upon the land, and since 1882 they have adopted a complete supplementary scheme of land irrigation, by which the whole effluent from the precipitation tanks is afterwards filtered through land. This is done at the comparatively small additional cost of £2,116 a-year. It is found that the sewage, after the lime process, is quite as valuable for irrigating as in its crude state. This was to be expected, seeing the effluent still contains in solution almost all the ammonia, and is freed from the grosser matters in suspension which tend to clog the land. The total area acquired by this Board for sewage purposes is 1,245 acres. Upon 1,135 acres of this land—only 40 acres of which is fallow—the whole sewage effluent of a population of about 650,000, amounting to a daily average of from sixteen to twenty million gallons, is utilized and very satisfactorily purified.

Again, Nottingham, with a population of about 240,000, has, since 1880, satisfactorily purified the whole sewage of the town by simply irrigating land with it in its crude state. The total area acquired in this case is 640 acres. About 530 acres of this—only 30 acres of which is fallow—receives the whole crude sewage of the 240,000 people, its average daily volume being from six to eight million gallons.

Nottingham uses about 25 per cent. more land of similar filtering capacity than Birmingham. This, in my opinion, shews very fairly the difference in the proportion of land required with and without previous precipitation in tanks.

Now, without multiplying instances, these are examples of irrigation on a large scale, upon which calculations can confidently be based.

The ordinary volume of sewage from Glasgow and suburbs now proposed to be embraced, with a total population of about 750,000, is estimated at from forty-five to fifty million gallons per day. (I presume that when the sewage of

Glasgow comes to be intercepted and dealt with, it will be necessary, under any scheme,—unless the purification works are to assume altogether undue proportions,—to provide for the natural streams and storm water running right into the river). The foregoing estimate is, as nearly as may be, *seven* times the volume at Nottingham, where the population is about 32 per cent. that of Glasgow and suburbs; and almost *three* times the volume at Birmingham, where the population is 86 per cent. that of Glasgow and suburbs. Looking at the respective populations, the volume in Glasgow is out of all proportion,—the result of various causes, the chief of which is our larger water supply,—so that we must, for our present purpose, set aside the *population*, and take as a basis of calculation the estimated *volume* of the sewage. And as Nottingham irrigates with the *crude* sewage, we shall take it as forming the best comparison. Multiplying the area irrigated at Nottingham, which is about 530 acres, by seven, gives 3,710 acres as the requisite area in the same proportion for Glasgow. The soil available for Glasgow in the valley of the Clyde, although for the most part a good loam for irrigation purposes, is somewhat denser than that of the Nottingham farm, and our rainfall is, unfortunately, greater. The sewage, on the other hand, is more diluted, although it contains a larger proportion of excrementitious matter from water-closets. Under all the circumstances, I should say we require a rather larger proportionate area of land than at Nottingham. The Nottingham farm embraces fully 100 acres which have not yet been irrigated. It is, undoubtedly, useful to have some extra land in the working of such a farm; but it would not be advisable for Glasgow to acquire much more land to begin with than is absolutely necessary for the sewage filtration.

In round figures therefore I should say that, under skilful management, the present volume of sewage from the 750,000 inhabitants in question can be purified by irrigation upon 4,500 acres of the lands of Strathgryffe.

As pointed out by Mr. Gale, something like double that area, within the fifty feet contour, might be made available in the same strath, in addition to over 1,000 acres on the north side of the river. I am therefore satisfied that, on the flat lands referred to, there is a sufficient area of suitable land, practically free from a resident population, and lying at a convenient distance from the city, to form an irrigation farm for the sewage of Glasgow and suburbs; and also of Paisley, Johnstone, and Renfrew (which towns have a gross population of about 78,000), not only for the present, but also for many years to come.

Before going into the possible working arrangements of a Strathgryffe Irrigation Farm, I may first give some indication as to the mode of conveying the sewage to it. Of course I only suggest, as I do not profess to be an authority on engineering questions.

The natural collecting point for the sewage of greater Glasgow seems to be immediately below Govan, as indicated by Sir John Hawkshaw and Mr. Bateman. From this very point the flat strath I refer to stretches right away westwards for about seven miles. Here, as in Sir John Hawkshaw's scheme, could be the main pumping station; and I should prefer, as suggested by him and also by Mr. Gale, to syphon the sewage from the high-level main to its level on the south side of the river, and thus save considerable pumping. The mode of interception proposed by Mr. Bateman in his scheme No. 2, 1878, does not commend itself to me, although the point to which he collects the whole sewage does. In the receiving well or reservoir at this point below Govan, ribbed strainers could be used to catch any floating material which might affect the working of the pumps. From this reservoir the sewage could be forced through cast-iron pipes direct to the most suitable points on the farm, as is done at Berlin and Paris. At these points it would be delivered into open main carriers, and thence would flow through branches and distributing channels over the respective fields.

It seems to me, however, that a better plan would be to have the rising mains delivering the sewage into a large covered conduit, formed about fifty feet above Ordnance datum, and to a length of about a mile and a-quarter, on the ridge from North Hillington to Arkleston. Thence it would gravitate through pipes, syphoning under the White Cart, &c., into the open main carriers on the farm, as in the first case. This conduit would contain two or three hours' supply, and would act as a regulator of the pressure in the pipes. It would also, to some extent,—and this would be very important,—regulate the supply to the farm, and thus make the distribution more easily and more cheaply managed. I estimate that the amount Mr. Bateman puts down in his Scheme No. 2 as the probable cost of precipitation works at the out-fall,—viz., £130,000,—will cover the cost of the rising mains, conduit, and distributing pipes necessary for delivering the sewage on the land referred to.

I shall now give a few observations upon the practical working of a 4,500 acre irrigation farm on the lands of Strathgryffe.

Sewage farming is altogether a specialty in agriculture. To begin with, a comparatively small variety of crops can be profitably grown upon a sewage farm, if it be a necessary condition that a given volume of sewage (and that as much as the land can take) is to be purified upon it all the year round. In that case, Italian Ryegrass is *the* sewage crop *par excellence*. One sowing of it lasts at least two years. On English sewage farms it usually gives five cuttings in the year. On Strathgryffe (so much farther north) three or four cuttings could be counted upon. The soil of Strathgryffe is naturally well suited for growing ryegrass; and, fortunately, this crop is one of the best for making silage. Mangolds are the most successful *root* crop; and Swedes do fairly well also. Most *vegetables* can be grown with good results, but cabbages in particular. Other crops can, and must be grown, as the circumstances suggest and the market admits; but those named are the ordinary crops which would do best under a large application of sewage in such a climate as ours.

The consumption of a large production of these special crops points directly and almost exclusively to the establishment of dairy farming on a large scale. The dairy cows would be all stall-fed. Of the farm produce, cut grass would be their main food in summer, after which cabbages, then roots and silage until the grass came in again.

As the main idea, the whole area acquired could, therefore, be divided out into a series of competitive dairy farms, under one head. The present steadings could easily be adapted. Each farm must, of course, take its proportionate quantity of sewage continuously, and would shew its own nett results. The form and manner in which the dairy produce could best be marketed, need not be discussed here in detail; but the extent of the undertaking, and the requirements of the present day. point to the establishment of one central dairy factory. This factory would credit each farm with the amount of produce sent in, the price being regulated by the quality. It would, at the same time, account for itself as a separate manufacturing business.

In order to deal with the sewage upon a reasonably limited area, it would be necessary to have always a proportion of each sectional farm fallow, so as to properly filter all the sewage in summer. This would be secured by having the fallow ground turned over, say four or five times during the season. In winter, after the crops have been taken off, there would always be plenty of land over which to distribute the sewage; and experience has shewn that there need be no fear of getting it applied during frost. Neither need there be any apprehension of the land becoming satiated, as the moving of the soil will effectually prevent this. At Edinburgh, the Craigentinny Meadows, a portion of which is clayey soil, have not been turned up nor re-sown for some two hundred years, during all which period they have been intermittently flooded with sewage, and yet they are not satiated, but yield grass which sells every year at from £25 to £30 per acre.

In the cultivation of the land, which would for the most part be done by steam-power, it would be very important to move the sub-soil to as great a depth as a steam sub-soiler would work properly, so as to prepare a more efficient medium for the filtering of the sewage.

These are, of course, simply the bare outlines on which, it seems to me, such an undertaking could be organized and worked out.

With regard to the question of health, so far as I have been able to learn, there is no evidence that the operations of any sewage farm have proved in any way prejudicial to the health of the people employed upon it, or living in its vicinity; or that crops grown by sewage irrigation are in the slightest degree unwholesome, or productive of any injurious effects whatever.

We now come to look at the financial aspect of irrigation.

The whole financial result must, of course, depend upon the price to be paid for the land, and this is somewhat problematical. Exact estimates cannot therefore be given, and any figures I give in this connection can only be looked upon as suggestive.

I shall presume it would be necessary to promote a Bill in Parliament, giving borrowing powers and compulsory rights to acquire the necessary land, &c. I shall also presume that Parliament would sanction, for this important public purpose, the compulsory purchase of the land required at its ordinary agricultural value, plus a fair and reasonable amount for compulsory sale and removal.

In that case I should not be far wrong in estimating the total cost of the land, including draining, forming carriers, levelling surface, and generally preparing it for irrigation, at £120 per acre. On the other hand, I estimate that, when fairly started, the irrigation farm thus prepared for receiving the sewage should, if well managed on the lines indicated, give returns which would admit of paying the interest on the Stock, and at least an ordinary agricultural rent, say 45/ per acre.

Assuming this result, and taking the extent and price of the land as I have suggested, and the borrowing rate at three per cent., we have the following estimate:—

Capital Outlay (*Irrigation only*)—

4,500 acres land at £120, - - -	£540,000
Stock, &c., for Irrigation Farm, say -	80,000
Total Capital outlay for Farm, - -	£620,000

Annual Charges (*Irrigation only*)—

£620,000 at three per cent., - -		£18,600
Less Interest on Stock—£80,000 at three per cent., - -	£2,400	
Less Rent, 4,500 acres, at 45/ per acre,	10,125	
		12,525
Estimated loss on Farm, to be paid from rates,		£6,075

This estimated loss of £6,075 (equal to a rate of one-third of a penny per £), is, in other words, the estimated cost of purifying by irrigation the whole sewage of Glasgow and suburbs, with a population of 750,000. As against this, it will be remembered, Mr. Bateman estimates the cost of chemical precipitation at the out-fall at £1,000 per annum for each million gallons per day, with an additional £10,000 a-year for the disposal of the deposit sludge.

Basing the cost of interception works (which are necessary under any scheme) upon the calculations of Sir John Hawkshaw and Mr. Bateman, and assuming the borrowing rate to be three per cent., the probable cost of a complete interception and irrigation scheme on the lines indicated, may be stated as follows:—

Capital Outlay (*Total*)—

Irrigation Farm and Stock, as above, -		£620,000
Interception Works and Pumping Station below Govan (practically part of Sir John Hawkshaw's scheme), say -	£650,000	
Rising Mains, Conduit, and Piping, to deliver sewage on farm, say - - - - -	130,000	
Preliminaries, contingencies, and Interest during construction,	100,000	
		880,000
		£1,500,000

Annual Charges (Total)—

Estimated loss on Farm, as above, - -		£6,075
Pumping at Station below Govan,	£5,000	
Interest on £880,000, at 3½ per cent.,	30,800	
Maintenance, say - - -	2,500	
		38,300
Total Annual Charge, - -		£44,375

This total annual charge (86 per cent. of which is for Interception Works), spread over the estimated rental of greater Glasgow,—£4,386,833,—is equal to rather less than 2½d. (2·42) per £.

It will be observed that the extra half per cent. interest, charged as above, makes provision for reducing the whole Capital expenditure on Interception Works in 66 years.

Supposing the Capital expenditure on land and stock were also to be entirely reduced in the same period (which is however unnecessary, seeing the land would form a good permanent asset), this would add £3,100 to the annual loss on the Irrigation farm, and would bring the total annual charge up to £47,475, which is equal to 2·59 pence per £ on the full estimated rental.

In the Appendix will be found some particulars relative to the respective places visited, which you may find interesting and useful for comparison. For these particulars, and for the kindness and courtesy extended to me on my tour of inspection, I have, in conclusion, to express my best thanks to the respective Burgh Engineers, Surveyors, and Managers connected with the various works and farms visited.

I am,

Yours faithfully,

JOHN YOUNG.

Cleansing Department,
234 Parliamentary Road,
Glasgow, *November, 1888.*

P.S.—I have also appended the Introductory and other Papers on "Sewage Disposal" read and discussed at the

Annual Meeting of the British Medical Association in Glasgow in August last, and published in *The Sanitary Journal* of October last and November current.

And I would further refer you to the Presidential Address, by Professor W. H. Corfield, M.A., M.D. (Oxon), F.R.C.P., "On the History of Sewage Disposal Enquiries," read to the Society of Medical Officers of Health, 19th October, 1888.

J. Y.

APPENDIX (A).

SUPPLEMENTARY NOTES AND EXTRACTS RELATIVE TO SEWAGE DISPOSAL WORKS IN OPERATION DURING THE TIME OF VISIT—AUGUST AND SEPTEMBER, 1888.

BIRMINGHAM.—PRECIPITATION WORKS AND IRRIGATION FARM. —In a lucid and interesting paper, entitled "The Work of the Birmingham Tame and Rea District Drainage Board," written by Mr. W. S. Till, C.E. (Engineer to the Board), and read at the meeting of the British Association on 4th September, 1886, the author, who kindly presented me with a copy, gives the history and results of these works up to that date. The following notes from this paper may therefore be found worthy of notice:—

Birmingham, situated near the summit of the Great Trent Watershed, was one of the first towns which felt and grappled with the sewage difficulty.

In 1853 the Corporation of Birmingham constructed the first intercepting sewers to the outlet at Saltley, where subsequently tanks and other works were constructed. In 1859 the precipitation process was first started. In 1872, however, in order to secure a better effluent, the lime process was supplemented by partial irrigation. In this direction the works were gradually developed, until, at the date of the formation of the District Drainage Board, "the Corporation possessed land and works thoroughly capable of purifying, so far as precipitation by lime could purify, the sewage of the borough."

After a Government inquiry the Borough of Birmingham and its neighbours, the Local Government Districts of Aston Manor, Handsworth, Smethwick, Balsall Heath, Harborne, and Saltley, and the contributory places of Aston, King's Norton, and Northfield and Penny Barr were formed into a United District, the Provisional Order coming into operation on the 29th September, 1877. In accordance with that order, the Board purchased all existing lands and works for the treatment of sewage owned by the various constituent authorities. The Saltley works, acquired from the Borough of Birmingham, formed the natural outlet for the whole district. Hence the other lands and works were soon after disposed of, and the whole sewage, only a trifling quantity of which requires pumping, was directed to Saltley. Here the outfall works were meanwhile extended, and, after due consideration, it was decided that the application of the sewage to land, after partial treatment by lime in the tanks, would be the most satisfactory method of purification. The earliest opportunities were accordingly embraced of acquiring additional adjoining lands. The result was that, in 1880, 1227 acres of suitable land had been secured, over which, with the exception of about 100 acres, the sewage flows by gravitation; and in 1882 the system of supplementary irrigation was complete. The Board farms the whole of the land, no portion of it being sublet. The sewage flows from the tanks at Saltley to the centre of the irrigation farm at Tyburn, a distance of 2¾ miles, in a conduit 8 feet in diameter. It is drawn from this conduit into open brick carriers, which again discharge into secondary carriers of earth, and thence into the flooding carriers. The brick carriers are constructed with only a slight fall, jumps being provided in the inverts at suitable intervals for drawing down the water.

The statement of income and expenditure for 1885 shews the balance cost of the Precipitation Works to have been £11,491 6s. 3d., and of the Irrigation Farm £2,813 14s. 2d. additional.

Remarking upon this statement, Mr. Till concludes his able paper as follows:—"The great loss, as will be seen from the statement, is in the work of Precipitation at the outlet (which comprises the lime, wages, machinery, expenses, and other charges connected with intercepting and dealing with the mud from the tanks). The amount expended under this head (exclusive of rent) was £10,715, for which sum 4,778 tons of lime were provided for precipitation, and 135,476 cube yards of mud were arrested in the tanks and dug into the land; the corresponding income is practically *nil*. Since the opening out of the irrigation land the expenses of Precipitation at the outlet have undergone some reduction, and there is every prospect not only of a further reduction in the future, but also of a gradual increase in the receipts from the Irrigation Farm as the demand for the farm produce is developed; but, bearing in mind the large initial outlay in purchase of land and the construction of works, and the annual expenses in disposing of so large a volume of sewage, it is not to be expected that assistance from the rates can be dispensed with until, in the somewhat distant future, the large annual sum now required for interest and repayment of loans shall cease. It should, however, be remembered, in dealing with sewage farm accounts, that, after all, the great item on the credit side of the balance-sheet (although it is one that cannot be represented by a money value) is the satisfactory disposal of the sewage."

In reply to my queries and inquiries on the spot, Mr. David Tough, who has had 21 years' experience of sewage farming (although he has only been two years farm manager at Birmingham), went to considerable trouble to give me the following supplementary details up to date:—

The population of drainage district is about 650,000; the area is 47,275 acres; the rainfall about 22 inches per annum; the water supply 16 million gallons per day; and the daily average volume of sewage dealt with from 16 to 20 million gallons. The Precipitation process commenced in 1859, partial irrigation in 1872, and complete irrigation in 1882. The total area acquired for sewage purposes is 1,245 acres, of which 1,135 are irrigated with sewage, and of this 40 acres are fallow. 888 acres are freehold, at an average cost of £135 per acre; and 357 acres are leasehold, on leases ranging from 20 to 99 years, at an average rent of £5 10s. per acre. The land is flat, and consists of a dark loam with gravelly subsoil. About £50 per acre have been spent on draining, levelling, constructing carriers (which are chiefly of brick), fencing, road making, &c. The common drains are from 4 to 5 feet deep, and 2 poles apart. To land under crop the sewage is applied not more than 48 hours at a time, and is shut off for an interval of from three to six days; but this depends upon the crop grown. To *fallow* land it may be applied for a month at a time. Ryegrass lasts two years, and gives five to six cuttings per annum. Very little silage is made. There are from 200 to 300 persons employed on the farm. The live stock consists of 170 dairy cows, 145 feeding cattle, 36 calves, 54 horses, 8 colts, 173 pigs, 262 sheep, and 155 lambs. All the produce not used on the farm meets with a ready sale in local and other markets, and makes average prices. There are no complaints whatever of injurious effects to the health of persons or animals on or near the farm. During frost no difficulty is experienced; the constant application of sewage removes the frost from the ground. Sewage farming can be continuous on the same land, when the heavier portions of the mud are removed and dug in. The width of irrigation ridges is from 44 to 66 feet. A good many syphons are used in crossing roads, &c., and they work perfectly satisfactorily.

The effluent, which flows in outfall channels from one mile in length upwards, to the river, seemed very satisfactory. The little specks of flocculent matter visible were evidently iron oxide from the subsoil.

I may add here that the night-soil removal in Birmingham is largely conducted on the pail system, and water-closets are comparatively few.

The following statements have been kindly supplied by Mr. Tough:—

Precipitation Works.

Expenditure, 1887.

	£	s.	d.
Wages, ...	£5,363	9	3
Lime for disinfecting, ...	2,563	4	5
Horse-keep, Veterinary Attendance, Repairing Carts, Harness, &c., ...	404	12	2
Timber, Ironwork, Bricks, Tools, Coal, Coke, and Repairs to Machinery, ...	1,125	9	6
Horse-hire, Boat-hire, and Tonnage, ...	53	4	2
Carried forward, ...	£9,509	19	6

Brought forward, ...				£9,509	19	6
Rent, £527 14s. 1d.; Rates and Taxes, £269 10s. 3d.,				797	4	4
Gas and Water, £67 10s.; Horse, £47 10s., ...				115	0	0
Miscellaneous Payments, ...				126	3	6
				£10,548	7	4
Income.						
Sale of Manure, ...	£21	9	0			
Pumping Sewage, ...	104	0	0			
				125	9	0
				£10,422	18	4

IRRIGATION FARM.

Expenditure, 1887.

Wages, ...	£6,054	12	1
Seeds, Plants, &c., ...	616	14	11
Horse-hire, keep, and Cattle-keep, ...	4,089	3	3
Stock purchased, ...	8,008	15	3
Miscellaneous Expenses (including Tools), ...	1,201	16	2
Rent, ...	3,477	10	4
Rates and Taxes, ...	848	11	0
Gas and Water, ...	149	4	1
	£24,446	7	1

Income, 1887.

Sale of Ryegrass and other Crops and Cattle Ley, ...	£6,581	14	4			
Sale of Milk, ...	3,861	9	10			
Sale of Stock, ...	9,777	0	10			
				20,220	5	0
				£4,226	2	1

Valuation, 1887, ...	£19,214	16	6
„ 1886, ...	17,914	19	10
	£1,309	16	8
Spent on Capital Work out of Revenue,	800	0	0
	£2,109	16	8

Loss on Farm, ...	£4,226	2	1
Less	2,109	16	8
	£2,116	5	5

The Farm shews a nett loss of £2,116 5s. 5d., or in other words, pays £1,361 4s. 11d. towards rent, or a little over £1 per acre.

Capital Expenditure to 31st December, 1888.

	£	s.	d.
Purchase of Old Lands, ...	£56,337	7	2
Works on Old Estate, ...	97,335	5	9
Stock, Plant, &c., Old Estate, ...	21,791	15	1
Steam Plough and Boat, ...	936	9	4
Purchase, Freehold Land, Timber, &c., ...	110,128	15	7
New Farm Buildings, ...	11,950	0	0
Open Carriers and Repairs, Old Buildings, ...	8,950	0	0
Farm Stock and Plant for New Estate, ...	8,000	0	0
Works of Sewage Disposal, ...	3,500	0	0
Purchase of Land, ...	16,250	0	0
Works of Sewage Disposal, ...	13,290	0	0
Outlay on Farm, &c., ...	1,646	8	8
Works of Sewage Disposal, ...	2,800	0	0
Costs of Raising Loans, ...	2,974	17	8
	£355,890	19	3

The amount to be contributed in 1887 by the constituent authorities forming the Board was £35,510 14s. 6d., which was made as follows, viz.:—

	£	s.	d.
Interest and Repayment of Loans,	£19,666	1	1
Management Expenses, ...	1,795	13	0
Balance, Outlet Account, ...	10,422	18	4
Do., Farm Account, ...	4,226	2	1
	£35,510	14	6

The quantity of mud arrested in the tanks at Saltley Farm during 1887 was 147,952 cube yards, or an average of 405 cube yards per day. Of this quantity 3,805 cube yards were removed by steam crane, and either sold to farmers or used upon the Tyburn farms, whilst the remaining portion was dug into the land—44 acres of the farm being used for that purpose. The total quantity of lime used for treating the Sewage was 4,123 tons, or an average of 11 tons 6 cwt. per day.

The yield of milk for the year was 130,628 gallons, the average from each cow exceeding 800 gallons.

The following is a summary of crops grown in 1887 :—

Grain.—30 acres wheat, 90 oats, and 17 beans.

Roots.—108 acres mangolds, 60 swedes, 41 greentop turnips, 34 kohl rabi, and 23 rape.

Vegetables.—120 acres cabbages, 64 potatoes, 2½ celery, 2½ cauliflower, 8 parsnips, 7 carrots, 2 brussel sprouts, 3 rhubarb, 2 kidney beans, and ½ lettuce.

Rye Grass, &c.—110 acres rye grass, 6 vetches, 9 rye, and 200 acres grass made into hay.

The average prices of crops per acre were as follows :—cabbage, £24; do. (Drumhead), £20; carrots, £32; celery, £81 16s.;

cauliflower, £26; parsnips, £20; potatoes, £25 16s.; brussel sprouts, £16 14s. 6d.; lettuce, £86 1s.; rhubarb, £53 11s.; kidney beans, £28 16s. 6d.; peas, £21 17s. 6d.; turnips, £16 4s.; rye grass, £19 13s. 2d.; rye, £9; and vetches, £8 7s. 6d.

The live stock bought and sold in 1887 was as follows:—*Bought*—382 beasts and 5 calves, 335 sheep, 31 pigs, and 9 horses. *Sold*—406 beasts and 50 calves, 600 sheep, 151 pigs, and 9 horses.

NOTTINGHAM.—SEWAGE IRRIGATION FARM.—This farm lies about four miles from the town. It is flat, and has been laid out in a very tradesmanlike manner. The soil is not naturally rich, but of a sandy nature, with gravelly subsoil. The whole sewage of the town (except a small portion which is raised some 6 or 8 feet by pumping) flows by gravitation through a covered conduit to the nearest point of the farm. Thence the main open carrier, constructed of concrete (1 of cement to 8 of gravel), runs across the centre of the farm, with branches of similar construction running right and left to the extremities. The fields adjacent to the main are supplied from it direct by outlets about 85 yards apart. The distributing channels, opened by the plough, are 4 poles apart, each being formed on the crown of a very slight ridge. From these channels the sewage gently finds its way over the whole surface. The main carriers are constructed almost level, and drop in steps at the junctions of the branches. This arrangement admits of the main carrier being used, when necessary, as a small reservoir. Although Nottingham is not, generally speaking, a water-closeted town, the sewage contains a large proportionate amount of polluting matter. The effluent, which is all collected into one outfall channel, appeared quite satisfactory.

To Mr. Avis, the intelligent manager who laid out and superintends the farm, and who kindly shewed me over it, I am chiefly indebted for the following information:—

The population of Nottingham is about 240,000; the area, 9,960 acres; the average rainfall, 27·13 inches per annum; the water supply, 20 gallons per head per day; and the daily volume of sewage dealt with from 6 to 8 million gallons. Overflows are provided for the storm-water. The irrigation works were commenced in 1878, and the first sewage was applied in 1880. The farm extends to 640 acres. About 530 acres of it are irrigated, 30 acres are fallow, and all the remainder is under crop. The whole farm is taken on a long lease, at a rent of £5 per acre. The Corporation has spent £4 10s. per acre in levelling the surface, from £7 to £8 per acre in constructing carriers, and about £4,000 in erecting extra farm buildings. They have also done the necessary draining. The common 4-inch pipe drains are generally 4 feet deep, and about 2 poles apart. The main 12-inch pipe drains are 6 feet deep, and about 8 poles apart.

(Mr. Avis puts great stress on having sufficient main drains, into which common drains can empty freely, and so prevent the soil getting water-logged). 150 acres, intended for special filter beds, have the drains only 10 feet apart. The crops grown on the irrigated land this year were as follows:—Italian ryegrass, 70 acres; grain crops, 150 acres; pasture and meadow, 100 acres; cabbages, 100 acres; mangold, 40 acres; and other crops, 40 acres. The ryegrass lasts two years, and gives five cuttings each year. Some of it is made into silage, in weighted stacks 8 yards long by 4 yards wide. The following animals are kept on the farm:—From 200 to 250 head of cattle, 70 to 90 of which are dairy cows; horses, 40, 30 of which work on farm; and 50 pigs. The wages paid to employees run from £20 to £30 per week; average, £30. No difficulty is experienced in applying the sewage during frost. The land does not get satiated. There have been no complaints of any injurious effects to the health of persons or animals on or near the farm. The financial result is, that the farm sometimes pays half the rent, but always some part of it.

LEICESTER.—The Corporation of Leicester established works for the chemical precipitation of their Sewage so far back as 1856. After 20 years' experience, however, they have abandoned their works, and given up the precipitation idea. They have now acquired land upon which to purify the whole sewage by irrigation. The reasons stated for giving up the precipitation process are—"The town had outgrown the works; there was great difficulty in getting rid of the accumulated sludge; and injunctions were threatened with respect to the effluent turned into the river."

The population of Leicester is about 145,000; the volume of sewage about 9 million gallons per day; the average rainfall 30 inches per annum; the water supply about 20 gallons per head per day. The Corporation has recently purchased, for irrigation purposes, 100 acres land at £125 per acre, and leased 1,275 acres for 30 years, at £2 5s. per acre. The surface of the land is undulating, the subsoil chiefly clay, but some sand. The sewage will require to be pumped to a height of 162½ feet, and a distance of some 3,000 yards to the farm. The works are still in preparation.

These particulars were kindly supplied to me by the Burgh Surveyor, Mr. J. Gordon, M.Inst., C.E., and he adds:—"We are carrying out a system of new main trunk sewers, which, amongst other improvements that they are to effect, will reduce the volume of sewage by the exclusion of a great amount of subsoil water.

CROYDON.—The two irrigation farms at Croydon—established in 1860—are still carried on very much as they were in 1877, and the general conditions are the same. See Deputation Report (Appendix), pages 35-37.

The system carried on here is rather different from the Birmingham and Nottingham systems, inasmuch as the land is not under-drained, and the sewage flows to a greater extent *over* the surface. The consequence is (and the slope of the farms admit of it), that it requires to be caught up and used two or three times over before dismissal at the outfall.

The area of the smaller farm of stiff clay soil has hitherto been only 65 acres, but now 82 acres more of the adjacent land on a higher level have been added to it. It will be necessary to pump the sewage on to this new land, and plant is being put down for the purpose.

The following particulars were kindly supplied by Mr. Thomas Walker, C.E., Burgh Engineer, and refer specially to the chief of the two sewage farms at Beddington:—

The population of the burgh is about 94,000; and the sewage from 74,000 flows by gravitation to Beddington. The area of the burgh is 9,014 acres; the rainfall 25 inches per annum; the water supply 30 gallons per head per day; the volume of sewage 3½ million gallons in dry weather, and 9 million gallons in wet weather.

Beddington farm has an area of 525 acres of most suitable land for irrigation, but the sewage is applied to 420 acres only. The purchase price of it was £264 per acre; previously it was rented at £10 to £12 10s. per acre. The cost of laying out the land, including draining and carriers, was about £20 per acre. There has been also spent on buildings £5,103; on effluent outfall £1,250; and on solid sewage extractors £4,161. The working expenses per annum amount to £4,300, while the revenue from crops, &c., amounts to £5,000.

The crops grown this year on the irrigated land were:—Rye grass, 210 acres; old ley (lea), 100 acres; mangolds, 106 acres; and osiers, 4 acres. The sewage is generally applied for three days continuously, and then shut off for about six days. Rye grass lasts 3 years, and is cut not less than four times a-year. About 14 horses are used on the farm. The crops are all sold. No cows, cattle, or other live stock are kept, and no silage is made. (An enterprising dairyman has, however, established a large dairy on a piece of ground feued off the farm, and he buys grass, &c., from the corporation). About 40 persons are employed on the farm. Only one syphon is used in crossing a road, but it gives no trouble whatever. There are no complaints as to injurious effects to the health of persons or animals on or near the farm. During frost there are no difficulties to overcome; the sewage goes on to the land as usual. The effluent at such times may not be quite so pure, but still good. Sewage farming can be continuous on the same land for ever; if well managed it does not become satiated, but if badly managed it might become sewage-sick in six months. The effluent flows for about 500 yards in a fine clear stream, to the River Wandle.

WIMBLEDON. — Like Croydon, Wimbledon discharges its drainage into the River Wandle. In this case the Local Board treat the sewage, and render it odourless by a compound mixture of chemicals, and finally purify it by filtration through land. I did not visit this place, but the following extracts are taken from a very exhaustive paper (a copy of which the author kindly sent me) on the "Wimbledon Main Drainage and Sewage Disposal Works," by Mr. W. Santo Crimp, Assoc. M.Inst., C.E., F.G.S., Burgh Surveyor, read to the Society of Engineers in April last:—

The population of the district is about 25,000, and its area is 3,220 acres. The sewage disposal works comprise the necessary tanks for the chemical treatment of the sewage, and 73 acres of land for its further purification. The chemicals used for Precipitation are lime and "Spence's" alumino-ferric, or sulphate of alumina, in the proportion of 8 grains of the former and 6 of the latter per gallon of sewage. In very hot weather it was found that a slight odour was given off from the land where the treated sewage was subsequently applied, but during the past hot summer much benefit has been derived by the addition to the clarified sewage of 2 to 3 grains per gallon of permanganate of potash. The nominal flow of the sewage is 750,000 gallons per day; the lime used amounts to 7½ cwts., costing 7s. 6d.; the sulphate of alumina to 5¾ cwts., costing 16s.; wages, 4s.; total, 27s. 6d. Thus, the cost per million gallons would be 35s. The sum of £25 may be added to the annual cost at Wimbledon for the permanganate of potash used in hot weather. This brings up the cost of chemicals alone to nearly £530 a-year. The sludge is swept from the settling tanks into a reservoir, whence it gravitates into the receivers, being then forced into filter presses by air pressure. Mr. Crimp calculates that one machine, with 24 plates 36 inches in diameter, will be necessary for 12,000 persons, if worked by day only; the production of sludge cake, with about 54 per cent. of moisture, will be about 2¼ tons per week per 1,000 persons; the working expenses for pressing at Wimbledon now amount to 2s. 4d. per ton of cake.

The original sewage farm consisted of 47 acres of stiff clayey land. As the population increased, 26 acres additional were purchased, and it all lies within five miles of Westminster Abbey. The effluent from the original farm is applied to the surface of the new portion a second time.

The crops grown are Italian ryegrass, 54 acres; mangolds, 10 acres; osiers, 6 acres; and vegetables, 3 acres. The ryegrass, which is mostly sold to cow-keepers in the south-west of London, gives five to six crops yearly; the average weight taken off per annum in the green state being 54 tons. The weight of mangolds produced last year (1887) exceeded 40 tons per acre. The vegetables and other crops are sold at fairly remunerative rates. The total receipts from produce for the year ending 25th March, 1888, amounted to £1,420, or nearly £20 per acre; while the inclusive working expenses were £910, thus leaving a balance of £510 towards repayment of interest and principal on moneys borrowed for the purchase of land and construction of works.

The cost of machinery, buildings, works, &c., was	£20,866	0	0
The 73 acres land, including draining and laying out, ...	32,573	0	0
Total, ...	£53,439	0	0

The annual payment in respect of this sum is £2,869; pumping and maintenance of machinery costs £520 per annum; precipitation of sewage and sludge pressing, £811; or a total of £4,200. From this deduct profit on farm, £510, and the net annual cost is £3,690, equal to a rate of 6·15 pence per £ on the present rateable value, and 2s. 11d. per head of the population.

OXFORD.—At Oxford the sewage contains a large proportion of excremental pollution, the town being exclusively water-closeted, and having a complete double system of sewers. Of course there are no manufactures in Oxford. The whole sewage is, and has been since 1880, purified by filtration through land. The sewerage works are very complete, and the pumping station is a model; but there is not much to be said for the working of the sewage farm.

Mr. W. H. White, M.Inst., C.E., the able Burgh Engineer, very kindly gave me the information I asked for, and a copy of his admirable presidential address to the Association of Municipal and Sanitary Engineers in 1883.

The population of Oxford (extended) is about 52,000. The area of the district under the Local Board (extended) is 4,600 acres. The rainfall averages 25 inches per annum. The water supply is 27 to 28 gallons per head per day. The daily volume of sewage pumped to farm amounts to 1½ million gallons. The farm, which cost £5,300, contains 369 acres, 330 of which are irrigated, 30 acres being specially prepared for filtration. £14,000 was expended in laying out the 330 acres, including road-making, under draining, and levelling. The 30 acres specially prepared for filter beds are drained to a depth of 7 to 8 feet, the drains being 33 feet apart; the other 300 acres to a depth of from 3 to 6 feet and 22 to 66 feet apart. The surface of the farm is undulating. The soil of two-thirds of it is light and sandy; on the low grounds near the streams a deposit of peat overlies the sand. The remaining third is stiff in character. Since 1880, £1,000 have been paid out of the rates to keep the farm going. There have been no difficulties during frost, and no complaints of any importance from a sanitary or health point of view. The sewage is raised 54 feet by pumping; the cost of the well-equipped pumping station, including site, was £19,000; and the annual cost of pumping is about £1,000. The pumping station, at which there is an overflow for storm water, is two miles from the town, and over 1½ miles from the farm. The rising main pipe is 24 inches in diameter, and delivers into a brick receiver, whence the sewage gravitates over the farm.

DONCASTER.—I did not visit this town, but the following replies to my queries have been kindly supplied by Mr. W. H. R. Crabtree, C.E., Burgh Engineer.

The estimated population of Doncaster is 23,625; the area, 1609 acres; the average rainfall, 26 inches per annum; and the average water supply, 20 gallons per head. The daily average volume of sewage from Doncaster and district is five to six million gallons. The sewage farm was first used in 1872. Its area is 278 acres. Prior to its use as a sewage farm the land was part of corporate estate. The rent increased by sewage from 25/ to 60/ per acre. Present rate is 40/. The soil is light, with gravelly sub-soil, and the surface is generally flat, slightly undulating. The whole farm is irrigated—a small portion at a time. The cost of pumping station, rising main, and laying out farm, was £20,000. Only a portion of the lands have been drained; the depth varies from three to six feet, and the distance apart is 66 feet.

The Corporation do not conduct the farm themselves, but let it to a farmer at £550 a-year. There are no injurious effects to the health of persons on or near the farm, and the sewage can always be disposed of during frost. The sewage application is not continuous; they change about, having plenty of land. Only a small portion of the farm is deep drained for special filter beds. The sewage is raised 52 feet by two compound beam engines of 35 nominal horse-power, at a cost of about £300 a-year. In a portion of the town only is a double system of sewers provided. There is a large reservoir sewer, which takes all the sewage while the engines are stopped. The sewage, if largely diluted by storm water, passes into a storm overflow.

STOURBRIDGE.—In reply to my questions, Mr. William Fiddian, C.E., Surveyor to the Stourbridge Main Drainage Board, has kindly supplied me with the following information regarding their sewage farm:—

The population of the district is about 20,000; the area, 2,513 acres; the rainfall, 33 inches per annum; the water supply, 30 gallons per head per day; and the daily average volume of sewage, 530,000 gallons.

The sewage farm was started in 1884. Its area is 130 acres, and the purchase price was £5,250, including effluent-pipe-right of about one mile. The surface is sloping—moderately steep to flat; and the soil light loam, five or six feet to sand alone. The whole farm is irrigated, and the adjoining farmer pays to take sewage at intervals on his land. About £8 per acre was spent in preparing the land. This was chiefly for carriers; single drains only were required in depressions. Extra farm buildings cost £850, and two cottages, £450. The farm is not worked by the Board, but is let to a tenant farmer on a five years' lease, at £225 per annum. The crops grown are 20 acres ryegrass (which gives three and four cuttings per annum), 15 acres oats, 25 acres potatoes, 35 acres roots, 10 acres cabbage, and the balance market garden produce. Ensilage is now being made in stack. There are no injurious effects to the health of persons on or near the farm. During frost the sewage is used over a large area, especially on flat parts. The soil has no apparent tendency to satiation. The sewage is raised 145 feet by pumping. The pumping station, plant, &c., cost £5,000; the rising main, &c., £3,100, and the annual cost of pumping, including upkeep, is £500. Stourbridge has a double system of sewers.

EDINBURGH.—The celebrated Craigentinny Meadows are the oldest and, in some respects, the most remarkable example we have of irrigation with sewage. Nowhere is there clearer demonstration of the value of sewage as a manure; nowhere can stronger proof be obtained that land does not, after a time, necessarily get sewage-sick; and nowhere affords a better chance of establishing a case if sewage farming is in any way injurious to the health of persons or animals living in the vicinity, and partaking of its produce.

The valuable estate of which the irrigated meadows form part, belongs to Mr. Christie Millar, and extends to 450 acres. He farms it through a manager, Mr. Bryce, who succeeded his father in that position. The small burn, which is practically an outfall carrier of the sewage from the central district of Edinburgh, runs through the property. I was told by the manager, that for some 200 years, without interruption, 200 acres of meadow, consisting of 40 acres sand, 30 acres red clay, and 130 acres loam, have been irrigated with sewage gravitating from this burn; and that, during all that time, the yield has been at least 4 cuttings of grass per annum. To all appearance, if the sewage brook goes on for ever, so will the grass on the Craigentinny Meadows. The cowkeepers of Edinburgh, year after year, purchase the seasons growth at from £25 to £30 per acre, and they have to cut and cart it in to their cow sheds. Thousands of cows are fed on this grass, and no person, or cow either, seems ever to have been the worse for it. Thorough purification of the sewage is neither effected nor attempted. This is no business of the proprietor or his manager. Their business is simply to get the greatest good for their crops out of the sewage. They succeed by using any quantity they like, when, and as they like; and all it costs them is the wage of one waterman by day and another by night, attending to the floodgates.

FORFAR.—SEWAGE FARM.—For the following particulars I am indebted to Dr. Murray, Medical Officer of Health (who read a very interesting paper on "Sewage Disposal at Forfar," to the British Medical Association in August last), and also to Mr. Harris, Burgh Engineer.

Forfar is the first town in Scotland to adopt a complete scheme of sewage purification by application to land. Prior to 1880, when the sewage farm was started, the sewage was discharged into the Forfar Loch. This was put a stop to by the Earl of Strathmore raising an action of interdict in the Court of Session.

Mr. Bailie-Denton of London was called in to advise, and the present scheme was devised by him, and executed to his plans. He thus describes it (and the Kirkintilloch scheme is on similar lines):—

"The quantity of land prepared at Forfar to receive and cleanse the present sewage is confined to about 24 acres only, out of the total of 40 acres, and the mode of treatment adopted is intermittent downward filtration, combined with surface irrigation. The area of the land devoted to intermittent filtration is seven acres, leaving 17 acres for surface irrigation. The soil is of a free and open character, sandy and gravelly in parts, though occasionally partaking of a somewhat loamy character. The land may be described as admirably suited for the filtration of sewage; but in order to avoid all chance of supersaturation, a main underdrain, with subordinate drains, has been laid, which will keep down the subsoil water, and secure aëration, and so allow of perfect percolation of the liquid distributed over the surface of the ground. The filtration areas are laid out in a series of terraces, each terrace being on a perfect level, to be intersected by main furrows, traversing their whole length, with branch furrows cut at right angles to the main ones. The main furrows are deeper than the branch furrows, in order that they may receive the solid matter floating in the sewage, which will deposit itself in them, and allow the liquid to be distributed by the branch furrows evenly through the soil. The intermediate ground between furrow and furrow is planted with vegetables, the roots of which help themselves to what they require of the sewage, and will yield abundant crops. The terraces forming the filtration areas, and the delivery of the sewage to them, are so arranged that each terrace can receive its quantum of sewage separately from the rest, or two or three can be served at the same time, according to the quantity of sewage to be disposed of. After they have received their fill, the sewage will be turned on to other terraces, which, in their turn, will receive their quantum. By this means that intermittancy of application and consequent aëration, upon which the oxidation of the putrescible ingredients of sewage depends, will be effected. The fields laid out for wide irrigation are prepared very differently from the filtration areas, inasmuch as the sewage is distributed over them on the 'catch water' system, without any great alteration of the surface configuration. The distributing carriers follow the natural contour of the land. When filled, the sewage overflows their edge, and runs down the natural slope of the land towards the next carrier, which is again filled to overflowing. The whole will be under the charge of the 'waterman,' who controls and distributes the sewage in suitable quantities, by means of 'stops,' which he places in the carriers when required to check the flow."

The population of Forfar is about 15,000; area, 1,000 acres; water supply, 22 gallons per head per day; daily average volume of sewage, 300,000 gallons. The farm of 40 acres cost £4,000, and £1,500 was expended in laying it out. 30 acres, including the 7 acres of specially-prepared filter beds, receive sewage, and this is all under crop. No difficulties are experienced in applying the sewage to the filter beds during frost. The farm yields a revenue of £433, while the expenditure (including working expenses, taxes, &c., £230, and interest on capital outlay at 4 per cent., £220) amounts to £450; so that the farm purifies the sewage, and is very little of a burden on the rates. The sewage is raised 50 feet by pumping.

Dr. Murray, in his carefully-prepared paper referred to, remarks:—"The question for towns situated like Forfar is not how they may make a profit out of their sewage, but how they can get rid of it at the least possible cost to the ratepayers, and at the same time in the most satisfactory manner for the public health; and I think our present scheme has successfully fulfilled both these objects;" and he establishes his case.

PARIS.—The authorities in Paris have, for many years, been greatly exercised over the "Purification of the Seine." There, as everywhere else, many different opinions have from time to time been expressed on the question of sewage disposal. The outcome, however, has been, that the system of purification by land irrigation, which was commenced in 1869, has been gradually developed. At the present time nearly one-third of the whole sewage of the city is purified by irrigation upon the plain of Gennevilliers, and arrangements are now in contemplation for applying the whole remainder to land some miles farther down the river at Achères, including part of the Saint Germain Forest. This scheme was prepared by the Municipal Engineers. M. Durand-Claye, the late Chief Engineer, in his paper on the "Purification of the Seine," issued in 1885, gives a history of the interception, distribution, and irrigation works carried out by this department of the service, and their results. He also describes the scheme of extension and the steps taken towards carrying it out, and annexes plans explanatory of the whole project.

The solid excrements of the population of Paris are not allowed to get into the sewers. They are collected in pail-strainers and cesspools, and removed to the Forest of Bondy by a private company, who manufacture them into Poudrette. All the sweepings and detritus from the streets are, however, washed into the sewers. The secondary and main sewers on either side of the Seine deliver into a main intercepting sewer. The intercepting sewer or collector on the north side is the chief one. Its course is down the river side to the Place de la Concorde, where it strikes north-west to the general pumping station at Clichy, which is on the east bank of the Seine, opposite Asnières. The south side intercepting main passes, by two syphons, under the river at Pons de l'Alma. Its course thence is by the Arc-de-Triomphe, and it joins the chief collector only a short distance from the pumping station. The chief collector is 16 feet in height, 18 feet in breadth, and about

3 miles in length. The syphons under the Seine give no trouble whatever. The sluices are so arranged that they can be used simultaneously or intermittently. The sewage, in its descent, passes over a sloping grid, from which a man rakes off the straw and floating refuse. Once a-week or thereby a large wooden ball is dropped in behind the grid, and passes rumbling through the syphon to ensure that it is kept clear. At present some two-thirds of the sewage flows into the Seine below Clichy, but the scheme referred to provides for its being elevated at the general pumping station, and conveyed to Saint Germain for irrigation purposes. An arrangement has been made between the Government and the city, whereby the specified lands at Achères and Saint Germain, extending to 799 hectares (1974 acres), are let to the latter for 20 years at a rent of 98,400 francs (£2 per acre), with the option, on the part of the city, of purchasing the whole for 3,280,000 francs (£131,200) at any time during the lease. This price amounts to about £66 per acre.

In a most important and exhaustive "report made in the name of the Commission appointed to examine the (foregoing) scheme, having as its object the agricultural utilization of the sewage of Paris and the purification of the Seine," by M. Bourneville, Deputy of the Seine, and editor of the "Progrès Mèdical," "Medecin de Bicètre," &c., published in 1886, and reprinted with supplementary notes in the present year, the whole question is very fully discussed. After giving particulars of a long list of towns in this country and on the Continent, which had, with advantage, adopted irrigation, M. Bourneville says:—"The large experience of Gennevilliers confirms, in its turn, the great laws of natural purification and agricultural restitution, which are put in evidence by the numerous examples which we have quoted." He then goes on in detail to state a dozen objections which had been raised by opponents of irrigation. Each of these he discusses and disposes of in turn, and winds up as follows:—"In conclusion, the scheme which has been presented to you will have the happiest consequences on the purification of Paris and the Seine; it will constitute an incontestable agricultural improvement, and both the public health and the public purse will derive undoubted benefit from the system."

By the kindness of M. Bechmann, who succeeded, a few months ago, the late M. Durand-Claye as Chief Engineer, I am enabled to give the following information, supplied by him in reply to my questions:—

The population of Paris is 2,230,000; its area, 7,800 hectares (19,274 acres); the average rainfall per annum, 24 inches; and the total dry weather volume of sewage, 300,000 cubic metres (66,000,000 gallons) per day. Between one-third and one-fourth of the whole volume is purified by irrigation upon 650 hectares (1,600 acres) of land on the plain of Gennevilliers. Of this 650 hectares, only 6 belong to the City of Paris; the remainder consists of small allotments belonging to numerous proprietors, and in many cases cultivated by tenants. These irrigated lands let freely at from 300 francs to 400 francs per hectare (from £4 10s. to £6 10s. per acre). Kitchen garden produce is chiefly grown, and grasses; but fruit trees, nurseries, grains, and industrial plants, are also successful. The irrigation is continued without difficulty during frost, because the sewage is conducted in closed sewers, right on to the fields which it irrigates, and thus it retains a relatively high temperature. Irrigation at Gennevilliers dates from 1869. The irrigated surface has increased in the following proportions:—1872, 51 hectares; 1874, 121 hectares; 1875, 200 hectares; 1880, 450 hectares; 1885, 616 hectares; and 1887, 650 hectares. It increases according to the development of the canalization. Up to the present time the sewage has been supplied gratuitously to the cultivators. They are not bound to receive the same quantity all the year round, but as a matter of fact the quantities applied represent very nearly a regular fraction of the entire volume. None of the users contribute to the expense of pumping and distributing the sewage. With regard to the question of nuisance or danger to health, there were some complaints at the commencement, on account of the temporary cessation of the flow in the underground sewers, which was partly attributed to irrigation; but these complaints have entirely ceased since the establishment of five lines of drains. Chemical trials were made at the beginning, principally with sulphate of alumina; but they have been abandoned, because the operation was rather costly, and produced only incomplete purification. The City of Paris intend so to extend their system of irrigation as to utilize all the sewage, and to stop entirely the present inlets into the Seine. The pumping station at Clichy—machines, ground, and buildings—cost about 1,500,000 francs (£60,000). The cost of pumping the sewage is 0·011f. per cubic meter (40s. per million gallons); the distribution costs 0·009f. per cubic metre (32s. 9d. per million gallons). Part of the sewage used for irrigation (about one-third) is conducted by gravitation. The works at Clichy have three pumping machines, which are 150, 250, and 700 h.p. respectively. Each of the first two consists of a double centrifugal pump, driven by means of toothed wheels from a single cylinder horizontal Corliss engine. The third one is similar, but being of greater dimensions has three cylinders coupled. In ordinary working either the two machines of 150 and 250 h.-p. are used, or the one of 700 h.-p. only. The height to which the sewage is pumped is 11 metres (35 feet). It is forced through two cast-iron pipes, each 44 inches diameter, which cross the river overhead. They are laid under the Clichy Bridge. The ventilating stand-pipes on the farm, which rise to a height of from 9 to 18 feet, are placed at the highest points on the line of conduit, at no regular, but merely chance intervals. No special arrangements have been made for storm-water.

The sandy soil with gravelly subsoil at Gennevilliers, is very suitable for irrigation. The effluent was beautiful to look at; and the assistant on the irrigation works, who accompanied me, proved his belief in its purity by drinking a full glass of it.

BERLIN.—Berlin, with a population of 1,400,000, covers 6,178 hectares (15,266 acres) of the flat sandy plain which is characteristic of North Germany. The average rainfall in the year is 600 milometers (23·6 inches); the daily water supply is 72 litres (15·84 gallons) per head; and the volume of sewage (which has all to be raised by pumping) amounts to 100 litres per head, or a total volume of 140 million litres (30,800,000 gallons) per day. Previously to 1875, the whole sewage of the city flowed in open channels along the sides of the streets, and was discharged into the River Spree and the canals. In those days the houses were provided with separate cesspools connecting with the closets, so that, as in Paris, the solid excrements were intercepted. All that is changed now, however. As the outcome of the exhaustive "General Report of a Local Mixed Committee appointed to inquire into the subject of Canalization and Sewage Disposal," published at the end of 1872, a complete scheme of sewerage on the English system has been adopted, and, to a large extent, carried out. This canalization scheme embraces and goes hand-in-hand with corresponding irrigation works for purifying the sewage by application to land. The city is laid out into twelve drainage districts. In seven of these the works have been completed, and the system is in full working operation. The cesspools have been abolished, and everything from the water-closets is now flushed into the sewers. Each district has its own pumping station, whence the sewage is forced through cast-iron pipes to the sewage farm. Large tracts of land have been acquired on all sides of the city, but especially on the north and south, for irrigation purposes. The farms are, for administrative purposes, formed into four or five groups, and each group is controlled by a general manager. I visited No. 5 Pumping Station and its corresponding farm at Malchow. This station is close by the Spree, on its north bank. It fronts an ordinary street, and is right opposite dwelling-houses. The circular reservoir, about 40 feet diameter, into which the sewer flows, is in the yard near the entrance. A vertical strainer stands right across the centre of the reservoir. The floating material intercepted by this strainer is taken up and burned in the boiler furnaces overnight. The reservoir is covered with wood, on the level of the yard, and plenty of hatches are provided. At this station there are five Lancashire and two locomotive boilers, and two single and three compound engines for driving the pumps. The total h.-p. of the engines is 900, but in pumping the normal flow only about 350 h.-p. is used. The average dry weather volume pumped here is from 25,000 to 27,000 cubic meters (5½ to 6 million gallons). In wet weather it is about a-half more. This is the sewage from 300,000 people, living in 3,600 houses. It is forced through a 40-inch rising main, and branches to a height of 29 meters (95 feet), and the distance to the farthest off outlet on the farm is from 9 to 10 kilometers (5 to 6 miles). Overflows are provided, whereby the storm-water flows into the river direct. From a sanitary point of view this station is about as perfectly conducted as possible, the absence of anything offensive to sight or smell being quite remarkable.

At the farm I met Mr. Spinnola, the General Manager of this group of three farms, whose head-quarters are at Malchow. At the nearest suitable point on the farm the 40-inch rising main from the pumping station divides into four branches, with a diameter of 28, 20, 20, and 10 inches respectively; and these again in turn into 72 distributing branches (8-inch pipes), so that the sewage is discharged from closed pipes at 72 separate points on this group of farms. On a commanding point on the line of the largest branch is a stand-pipe about 80 feet high. An overflow to an open carrier is provided a few feet from the top of this ventilating pipe. By a float arrangement a flag by day and a light by night rises and falls with the pressure, and this forms a gauge or indicator to the chief waterman, and guides him in the distribution of the sewage. These farms are laid out in level rectangular plots, each containing about one morgen (96 poles). Each plot is surrounded by a trench and slight embankment. This trench is flooded from the carriers, and the sewage from it overflows the plot. About 1,400 such plots on the Malchow farm are let to market gardeners, and they get what sewage they want. For vegetable and root crops (which are grown in raised beds five feet wide) these plots are all cultivated by hand labour. They are only ploughed for grain crops. Some of the hand labour is supplied by homeless men (not criminals) from the House of Correction. The total area of the farm-group, which gives employment to over 600 work-people, is 1,300 hectares (3,212 acres), of which 1,020 hectares (2,520 acres) are irrigated with sewage. Only 620 hectares (1,532 acres), however, are irrigated during one season, the remaining 400 hectares (988 acres) or thereby, are sown with grain, and get no sewage for that season. About 180 hectares (444 acres), which are under irrigation, grow Italian rye-grass, which gives five or six cuttings in one season; and 440 hectares (1,087 acres) are taken up with mangolds, carrots, cabbages, and other vegetable and root crops. Some parts of the farm are drained 1 meter (39 inches) deep, and 5 to 6 meters (16 to 20 feet) apart. No land is kept fallow. There is no difficulty experienced in continuing the irrigation during frost, seeing the temperature of the sewage is 5° to 6° (41-43 Fahr.) In autumn, during the heavy rains, the sewage is applied intermittently to specially prepared filter beds, which are put under crop in the following spring.

At the Malchow steading, which at one time was a large distillery, I saw 70 milk cows and 60 working oxen all standing in one large shed, and there are 14 working horses besides. These animals use a considerable portion of the farm produce, but the great bulk of it is sold in Berlin. The cows are milked three times a-day, and a yearly contractor takes all the milk at fixed prices. The water supply is from a well in the yard, which, I was told, is not in any way affected by the application of sewage to the farm.

The present Municipal farms have a total area of 4,453 hectares (11,004 acres), of which only 2,744 hectares (6,780 acres) are irrigated; and only 1,505 hectares (3,719 acres) of the irrigated portion have been drained. It seemed to me, however, that the object aimed at is to irrigate as great a surface as possible with the sewage, rather than to purify it upon the smallest possible area. The chairman of the committee on canalization works has informed me that some complaints were made from a sanitary and health point of view at the beginning, but since the works have been completed no more complaints have been made, either with regard to the pumping stations or sewage farms. It is also said that the Medical Officer's reports demonstrate the harmlessness of irrigation with sewage. On account of the limited water supply, and the consequently small volume of sewage in proportion to the population, the sewage of Berlin is much more polluted, and correspondingly richer in ammonia, than that of any town I have visited in this connection. The idea of sending their valuable sewage to the sea is regarded in Berlin as an enormity. A special commission appointed by Government controls the service, and the annual reports by the Municipality publish the proceedings of the city and of this commission.

APPENDIX (B).

INTRODUCTORY AND OTHER PAPERS ON SEWAGE DISPOSAL, READ AND DISCUSSED AT THE ANNUAL MEETING OF THE BRITISH MEDICAL ASSOCIATION IN GLASGOW, AUGUST, 1888. REPRINTED FROM THE "SANITARY JOURNAL" OF OCTOBER AND NOVEMBER, 1888.

THE SEWAGE QUESTION IN GLASGOW.[*]

BY JAMES B. RUSSELL, M.D., LL.D.,
Medical Officer of Health, Glasgow.

THE disposal of sewage is a subject which has a very present interest to the community of Glasgow, and I am sure no part of the proceedings of the British Medical Association will attract more public attention, or raise greater hopes of local advantage, than the discussion now to be begun. In this view, I think the most useful contribution I can make to the proceedings is to give a very condensed statement of the history and present position of the question of sewage disposal as it affects Glasgow. The Association could not do a greater service to the community, which is now honoured with its entertainment, than by giving the discussion special reference to the difficulties of *their* sewage question. The practical utility of the advice of experts depends upon the extent to which their individual theories are adapted to the circumstances of the case upon which they are consulted. Within the drainage area of the Clyde there are "large towns," "small towns," and "country districts," presenting such variety of circumstances that nothing which can be said on sewage disposal can be entirely destitute of application to some item in the vast problem of its purification. The question which most interests the great community of which Glasgow is the centre is, What method is on the whole best suited to their circumstances?

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[*] Read as an introduction to a discussion on the Disposal of Sewage in Large Towns, Small Towns, and Country Districts, by the Health Section of the British Medical Association, Glasgow Meeting, 10th August, 1888.

The history of the Glasgow "sewage question" is the same as of every other sewage question, which exercises or has exercised the minds of the inhabitants of cities. The successive steps are sewers, water-supply, water-closets, polluted tributaries, then pollution of the main stream. The first common sewers were formed in 1790. The first common water supply was taken from the Clyde above the town in 1806, and supplemented from the same source in 1808. In 1831, we are told, that "till the formation of the Glasgow Water-works in 1806, there were very few water-closets in the city; but they are now to be found, not only in the first, but in the second and third rate houses."* At this date there were five miles of sewers laid down in 45 streets. They had been extended to 41 miles by 1848, and to 60 miles in 1860. Just as sewers extended complaints of the foulness of the numerous local tributaries of the Clyde arose, beginning with the Molendinar on whose banks the city was first planted. The visitation of cholera in 1832, 1848, and 1853, increasingly virulent within the area of the river water supply, shewed that even 2½ miles above Glasgow Bridge the Clyde had, from pollution of its upper reaches, ceased to be fit for dietetic use. The Gorbals Gravitation water, introduced to the south side of the river in 1846, shielded that portion of the city from the cholera of 1853, and Loch Katrine water, introduced in 1859, completed our safeguard, so that we have had no epidemic cholera since. By 1849 the pollution of the Clyde had thoroughly attracted public attention. It is remarkable that the references to its condition in the *Glasgow Herald* of that date were couched in language quite as emphatic and strong as any ever applied to the Clyde at the present time. Take the following, for example, in October, 1849:—"The effect of some thousands of water-closets pouring their contents into the Clyde cannot but be odious in the extreme; and any one may have felt, that in summer days, after a long drought, the river, from this cause, literally sweats abomination, and we have more than once seen people sickened from it on board the steamers." * If this was the state of things nearly forty years ago, what ought it to be now? The population in and about Glasgow has doubled. A water supply for all purposes, averaging forty million gallons per day, or equal to four-fifths of the volume of the Clyde in time of drought, is distributed and flows polluted to the river. Whereas, in 1864, there were only 28,000 water-closets within the area of the water supply, there are now 118,000. The tributaries which distressed our forefathers have gradually been dealt with, either by running culverts down their beds, and making them into sewers, or by intercepting the city portion of the sewage and conveying it direct to the Clyde. Public urinals abound. Water is applied freely with the hose in our back courts and closes, flushing their surface filth to the drains. In short, there are few cities in which more has been done to remove filth from the environment of the dwelling; but, excepting the diminishing proportion systematically removed by privy-pail and ash-cart, it has all been transferred to the river. Nothing in the sanitary operations of late years has ultimately advantaged the river except the improvement of our streets. Since the abolition of Road Trusts and the development of the tramway system, macadamized roads have been almost entirely displaced by granite run in with bitumen. The system of scavenging has also been greatly improved, so that the rain-washings must be much less foul. The interesting question remains, How is it that the offensiveness of the Clyde has not proportionately increased? The probable answer is, that the operations of the Clyde Trust have tended to dilute the sewage with a steadily increasing amount of impounded tidal water, and have also facilitated its removal seawards. Since 1849 the extent of quayage and the water area of the harbour have been tripled. The former, at this date, extends to over 6 miles, and the latter to 154 acres. The channel below the harbour has been straightened and deepened. The result is, that the Spring-tidal range has been increased from 2 feet 5 inches in 1755, to 11 feet 2 inches in 1888, of which 2 feet 8 inches have been gained since 1853. There is actually 14 inches more range between high and low water in the Harbour than at Port-Glasgow. In 1800 the time of high water was three hours behind Port-Glasgow, now it is only one hour. The effect of these changes in expediting the removal of sewage down the river has been shewn by careful experiments with floats. In 1858 a float took 43½ tides, or 537 hours, to reach Port-Glasgow, a distance of about 19½ miles. In 1879 it took only 10 tides, or 120 hours 40 minutes to reach Gourock, a distance of fully 24 miles. Roughly speaking, the sewage was removed seawards at more than five times the speed,

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* Cleland's *Enumeration, &c., for Census of 1831*, p. 262.

* *Glasgow Past and Present*, vol. i., p. 131.

or in less than a-fifth of the time. In 1879 there was a weir above Albert Bridge, which was removed; and after its removal in 1881, these float experiments were repeated. It was found that the rate of movement was somewhat less. I shall not trouble you with the precise figures, but this statement will seem more important to Glasgow citizens than to strangers, as the removal of the weir was expected to put still farther off the evil day of the sewage question. Another fact which helps to explain why the public expression of Glasgow opinion has not exceeded in recent years the intensity to which it had attained in 1849, is, that by the extension of railway communications on both banks of the river down to points in the open Firth, passenger traffic has been almost wholly withdrawn from the upper Clyde. Greenock was connected by rail with Glasgow in 1841, and all the other exits by rail to the Coast have been provided since 1849. The odours of the Clyde below the harbour are therefore now less familiar to Glasgow people than they were forty years ago. But the sewage question is not to be solved in this way. In fact you will recognise the natural sequence of events when I state that it has been transferred, as a burning question, to the lower reaches of the river. As we have seen, it began in the Molendinar. It was pushed into the Clyde, and now it has been partially removed to the Tail of the Bank and Loch Long! The 154 acres over which Glasgow Harbour and Docks extend form a huge settling pond, from which, last year, 610,000 cubic yards of more or less foul deposit was dredged, and transferred to Loch Long, at a cost, to the Clyde Trustees, of about 6d. per cubic yard, exclusive of interest on plant, which, Mr. Deas informs me, may amount to 3d. additional.

No prophet is required to tell us that, in the circumstances described, our sewage question will not keep much longer. It is not surprising, in view of public opinion in 1849, that it was found necessary to consult Mr. Bateman in 1853. In conjunction with the late Professor Anderson, he made a provisional report in July, 1858, in which, as the result of local experiments, precipitation was condemned, because, though effectual in deodorizing, the precipitate could not be sold at a price which would cover the cost. The 1858 float observations were also referred to as proof that the sewage must be conveyed "to a very great distance." This was an introduction to a positive opinion a few months later, in favour of engineering works similar to those then projected for London. The Town Council, with Scotch caution, resolved to wait until London had shewed the way. Meanwhile they were beset with all sorts of schemes, and in 1867 remitted them all to Messrs. Bateman and Bazalgette, in a minute which gives vivid expression to the bewilderment caused by a multitude of counsellors. They reported in 1868 in favour of a scheme by which the whole sewage could be conveyed to the Ayrshire coast, one-fifth by gravitation, and the remainder after an average lift of 32 feet. The area dealt with was Glasgow and suburbs, estimated at a population of 500,000, and providing for an increase in twenty years to 750,000. The actual sewage was 35 million gallons per day, independent of rainfall, or 70 gallons per head, of which 54 was water supply. The works were calculated to take a maximum flow of 110 million. The cost was estimated to be £1,253,256, entailing an annual charge of £55,000, which was equal to a rate of 5½d. per pound on the assessable rental of the area included. At an additional cost, not estimated, for pumping, works, land, &c., a suggestion of irrigation was made. As to available land, they made the important statement, subsequently confirmed by Sir John Hawkshaw, that "The total area of land within the valley of the Clyde, under a contour of 50 feet above Ordnance datum, suitable for the reception of the sewage, is about 9,500 acres, of which 1,500 acres are upon the north, and the remainder upon the south bank of the river below the city." They point out that the land on the north side lay close to residences, and in the way of the westward growth of the city; while in view of the claims of neighbouring towns only 7,000 acres could safely be taken on the south side. They therefore advised removal to the sandy land on the Ayrshire coast.

The next step was the Royal Commission to Sir John Hawkshaw, who reported, in 1876, on the entire drainage area of the Clyde. The scheme applicable to Glasgow and suburbs included also Coatbridge, Airdrie, and the towns along the course of the outfall sewer, which discharged at Farland Head, opposite the Little Cumbrae Island. The population thus served was estimated at 800,000. The actual sewage, including rainfall, was 120 million gallons per day, and the maximum flow to receive which the sewers were constructed was 50 per cent. more. The estimated cost was £2,500,000. The annual charge for pumping, maintenance, and interest, was £108,000, which meant a rate of 6½d. per pound on the assessable rental of the area dealt with. It is important to note that Glasgow and suburbs alone, Sir John Hawkshaw calculated, produced 48 million gallons per day, without rainfall, the proportion per head being 70 gallons, of which 53 was water supply.

Preliminary to the adoption of this scheme, Sir John recommended the appointment of a "Board of Sanitary Commissioners of the Clyde." An endeavour to carry out this suggestion by private Bill was unsuccessful, and Government has hitherto failed to implement a promise of general legislation for this purpose.

In 1877 the Town Council, by a deputation of their number, applied their own minds to the question, and came to the conclusion that the sewage of Glasgow might, "after being rendered clear by precipitation and filtration, be passed into the Clyde." Mr. Bateman was asked to supply an engineering scheme for this purpose, and suggested three, all of which ended in bringing the sewage to one or more points on the river above Dumbarton. A sentence thrown in at the end of his report raised doubts as to whether the clarified effluent would, after reaching the river, in the circumstances of tidal retardation previously described, be dispersed before again becoming offensive. This was a revival of the float experiments in 1858, but, as already stated, their repetition now shewed that the circumstances were entirely altered. Still, numerous laboratory experiments were immediately instituted by Dr. Wallace, at the request of the Council, with this result—"That Glasgow sewage, properly defecated, and introduced into the Clyde at a point below the City, will not, under any circumstances, give rise to a nuisance." The deputation in 1880 again made a tour of the various towns in England where sewage processes were in operation, and also investigated the Liernur system in Amsterdam. In the light of all the information thus obtained, they re-affirmed the conclusion arrived at three years previously. In 1881 the Sewage Committee adopted Bateman's scheme No. 3, by which the sewage of the north side was to be treated at Dalmuir, and of the south side at a point in the parish of Govan. The area dealt with extended to 14,900 acres, with an existing population of 710,000 persons, yielding 36½ million gallons of sewage per day, exclusive of rainfall. This is 51 gallons per head, of which 45½ is water supply. The works provided for 1,350,000 persons, yielding 62,500,000 gallons. Exclusive of cost of land and interference with property, this scheme was, according to a revised estimate, to involve an expenditure of £800,000 on works. The annual charge for pumping was £3,400. The cost of treatment was roughly estimated at £40,000 to £45,000 a-year. An idea was somehow suggested that the removal of the weir would for a time make the sewage question less urgent. Partly under the influence of that idea, and partly from the existence of so many administrative authorities among the sewage-producing community, this scheme was not further considered. I have already pointed out that the removal of the weir has certainly had no such effect, though other circumstances have gradually tended in some degree to mitigate the nuisance at our own doors.

There is some prospect of an extension of the municipality, so as to include the whole populous area, and I have no doubt, in that event, one of the first questions which will engage the consolidated Council will be the purification of the Clyde.

ON SEWAGE DISPOSAL FOR WATER-CLOSET TOWNS.*

By Alfred Carpenter, M.D.

It having been determined that "The Disposal of Sewage" be one of the subjects for consideration at this meeting, I think it right not to allow the most correct way of dealing with sewage to be put out of sight because of its simplicity. It is twenty-two years since I introduced a method of treating town sewage to the notice of an assembly of men of science, specially called to consider the subject of town drainage. That was at the Congress assembled at

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* Read in the Section of Public Medicine at the Annual Meeting of the British Medical Association in Glasgow, August, 1888.

Leamington in 1865. I have repeatedly followed up the same subject at various meetings of scientific, medical, and sanitary bodies, always dwelling upon the points connected with the utilization of sewage on land by so-called "broad irrigation." At the International Congress assembled in London in 1881, I submitted in general terms a series of propositions for the consideration of the Congress, and I now venture to re-state them, for the consideration of this meeting, in terms more explicit and detailed.

1. That the application of the sewage of a water-closet town to land in close proximity to dwelling-houses is not injurious to the health of the inhabitants of those houses, provided the sewage be fresh; that it be applied in an intermittent manner, and the effluent be capable of rapid removal from the irrigated fields.

2. The judicious application of sewage to soil of almost any kind, if it be mainly inorganic, will satisfactorily cleanse the effluent water, and fit it for discharge into any ordinary stream, provided the area treated is not less than an acre for each 250 persons.

3. That vegetable products grown upon fields irrigated by sewage are satisfactory, and safe as articles of food for both animals and man.

4. That sewage farms, if properly managed, do not set up either parasitic or epidemic disease among those working on the farm or among the cattle fed upon its produce.

5. That this immunity exists because the conditions necessary for the propagation and continuance of those disease germs which affect man and animals are absent; the microbic life on sewage farms being antagonistic to the life of disease germs, the latter, therefore, soon cease as such to exist.

6. That sewage farms may be carried on in perfect safety close to populations. It is not, however, argued that the effluent water is safe to use for dietetic purposes.

7. That there is an aspect in sewage farming which shews that it is a wise policy for the nation to encourage that form of utilization from a political economy point of view.

8. That to be financially successful such farms require that the rainfall be separated from the sewage; the area large enough for alternate cropping, and the capital employed sufficient to insure a continuous and rapid consumption of the crops produced.

9. That if practicable sewage utilization by surface irrigation should be, for financial reasons, within the area of its own watershed, and close to the populations producing the sewage; but it is not a necessity that it should be so, provided it be applied to the land within a few hours, not more than twelve, of its discharge, and that there is no arrest of movement for more than very short periods before it is so utilized.

Several years have passed away since the matter contained in those propositions was put forth to the medical profession. I now intend to carry on the evidence as to their soundness by reference to the experience which has been gained in various parts of the kingdom, since the last report to a medical body—namely, 1881, but more especially by the results which have followed its continued application to the same land in my own neighbourhood since that time.

There are two facts which no amount of argument derived from the use of chemicals, or the bungling of local authority officials can controvert or deprive of their significance:—

1. The utilization of sewage has been carried out on the same land consecutively for thirty years, frequently in a bungling manner, the area, however, being increased as the increase of population required it. Commencing with thirty-six acres only in 1851, it was all but abandoned as an incorrect proceeding, because the quantity of sewage applied was in excess of the power of the soil to deal with it. Three hundred acres were then obtained about the time that I first became connected with the farm. These have been increased by new purchases as the quantity of sewage to be applied from increasing population rendered it absolutely necessary to enlarge the area of application; but the land irrigated for the first time thirty years ago still continues in use, and effects its object as perfectly as on the first application. The subsoil of the farm two feet below the surface shews very little alteration, and three feet below is not in any way contaminated by the continued application of sewage. The various crops grown upon the land take out the manurial properties of the sewage, and allow the soil to continue its purifying power even better than at first. To effect this, however, it is necessary that the cropping be incessant, and that the land have occasional rest for a year from sewage application. The tendency of the repeated application of sewage to land is to silt up the lower portion of the subsoil, and prevent it acting as a filter below the plough level, except for a short time. It follows, therefore, that the sewage must pass over the land rather than through it; and although intermittent downwards filtration may purify the water, it will be temporary only, unless the soil is turned over frequently, so as to allow of its aëration. A sewage farm will bear deep ploughing better than other land, and grow larger crops in consequence.

2. The second great fact is that, notwithstanding the very large price paid for the land at Beddington and Norwood—namely, sometimes as much as £300 an acre, or more for some of it, and a total cost of nearly £250,000—it has seldom been necessary to make more than a 2d. rate upon the parish to meet all the charges required to be met. The capital raised is now being paid off, but not lost, and in forty years from the last loan the whole farm will be the freehold of the borough, without any liability at all upon it, paying a fair sum towards the reduction of the rates, and retaining a large open space, with abundance of vegetation, in the midst of a large population, and providing a considerable amount of out-of-door work. The capital raised is an investment for the future, and not a scattering of immense

sums of money in works which may become useless, like to those now being carried out by the Metropolitan Board of Works at the Thames outfall, by Crossness & Barking.

Let me take the propositions in turn:—1. As to the effect upon health.

I shewed that in 1881 the average death-rate for ten years for the Beddington and Wallington district was 14·3. I reproduce the table, with additions up to the present time. The deaths have not exceeded in number those in 1881, although the population has risen very considerably, and the births are twenty more than in that year. The rateable value of the district in 1861 was £11,700, in 1871 was £20,671, in 1881 was £41,616, and this year it is returned in the report to Surrey County Quarter Sessions as £47,424—a tangible evidence of the increase of wealth and population around the sewage farm; whilst the zymotic death-rate last year is 0·5 only, and the average on the last seven years is only 1·2.

As regards its effect upon the health of the burgh of Croydon, I shewed in 1881 that the average death-rate for the burgh was 17·9, and the zymotic death-rate 2·79. In 1886 it was 14·5, and the zymotic death-rate 1·53. In 1887 it was 14·7 and 2·2 respectively, the dry summer increasing the diarrhœa among infants.

I need not follow this head any further, except to remark that in February, 1887, I submitted a report upon the subject to the Society of Arts in London, in which I conclusively proved that in no single instance, out of nearly 100 cases in which sewage has been utilized by broad irrigation, had any fact been proved to establish the allegations of "insanitariness" which are sometimes raised against them.

2. As to the character of the effluent, it continues to be perfectly satisfactory. The analyses which are occasionally made by the Local Authority establish its maintenance of standard, which is very similar to that given by me to the International Congress, whilst no questions have been raised upon this point except whilst the Norwood Farm was overtaxed by excess of sewage. Dr. Angus Smith's report to the Local Government Board in 1879 was to the effect, that as regards this form of treatment of sewage it maintains its position—namely, "that in every respect the best results have been obtained by irrigation."

3 and 4. The third and fourth propositions need not be further discussed, for no proof has been even tendered to the contrary, except by Dr. Tidy in his communications to the Society of Arts, which were based upon suppositions made twenty years ago, not upon any solid foundations whatever,—a point I was able to prove conclusively in my reply to his paper before the Society of Arts, and to which I have already referred; and even Dr. Cobbold withdrew his antagonism before his death, because it was proved to his satisfaction that it was based upon idea only.

5. The fifth proposition is an important one. It is difficult to prove a negative. I assert that disease germs are of two kinds,

corresponding with active germs and resting spores—eggs hatched and growing, and eggs unhatched. The hatched eggs are rapidly destroyed by the physical conditions under which they arrive at the farm. Exposure to air, a lower temperature than that necessary for worm-blooded creatures, absence of pabulum, and presence of injurious gases, soon destroy their life; but the resting spores (unhatched eggs) are more persistent. They certainly arrive on the farm, and it might be expected that they would do mischief, and so they do (and would) if the sewage is not immediately applied to the land. But then, if arrested, Nature comes to our rescue, and destroys them by the sulphuretted hydrogen which is engendered as soon as putrefaction is rampant; but putrefaction destroys the chance of a satisfactory financial return from the use of the sewage, and it is not to be encouraged. As soon as the resting spores come in contact with the spongioles of plant life they are taken up with avidity, and taken in as food most energetically, much as human beings take in oysters when they get the opportunity. Some classes of plants, which I have presumed to name "carnivorous,"* among which I place rye grass, do assimilate these germs in the most rapid and satisfactory manner, so that no particle escapes their devouring power, and the effluent, as far as my observation goes, is absolutely free from their presence.

7. The seventh proposition is also a most important one. A Local Authority buys a site, and spends a large sum in erecting tanks and machinery for chemically treating sewage. If they give up the process the whole sum so expended is utterly lost. Not so the sums invested in the purchase of land. The capital is there, and every farthing taken from the rates is either left in the land, and raises its capital value by increasing its agricultural power, or sends into the country an additional supply of meat, milk, and vegetables, which make an actual addition to the wealth of the nation, although the locality itself may not apparently benefit by a reduction of taxation. The Corporation of Croydon have at this moment an estate of more than 700 acres, purchased for sewage farm purposes. Its agricultural value has been raised five times over since it has been so utilized, its power to employ labour correspondingly multiplied, to the advantage of the tradesmen and owners of cottage property in the borough, whilst the housewife has the choice of so much more milk and meat than would have been the case if no farm had existed. Let these conditions be established in five hundred other districts in the kingdom, including London, and pauperism will be correspondingly lessened, because so much more labour will be provided, at least 40,000 agriculturists kept on the land who are not now employed, the price of milk kept down, whilst thousands will have it who cannot have it now, and a mass of wealth added to that belonging to the country, which ought to recommend sewage

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* *Vide Sanitary Record*, 1875: "Power of Soils, Air, and Vegetation to Purify Sewage."

farming to all political economists who study production and its effect upon population.

8. The financial question contained in the eighth proposition is not medically interesting, but it affects us as ratepayers. I will only remark upon it that the greater the cost the greater the necessity of employing capital upon the land; and the greater the amount of produce raised, the greater the necessity for capital to be utilized in consuming it. The Croydon Corporation blindly allow their committee to waste the produce of the farm by preventing the consumption of produce on the farm, and thus play into the hands of cowkeepers and others who are able to get it at a cheap rate. This is a monstrous perversion of common sense, which is bearing fruit in the fact, that the receipts for produce on the farm, under its increased area, are less in amount than they were before the new land was added to the farm. But such is one of the penalties a town has to pay for electing representatives unable to deal with these questions from a broader view than that of self-interest for the moment.

9. The last proposition has reference to situation. The sooner the sewage is on the land the better chance for a good result on every point of view. If, however, the sewage has to be pumped, it increases the financial cost, and arrangements must be made for its rapid and continuous removal. If sewage is kept moving it may travel any distance. The farm may be forty miles from the town producing it; but if so removed the town must expect to pay a larger sum for cost of transit. This may be counterbalanced by cheaper cost of land. The expense of pumping can be calculated to within a few pounds, and if the rainfall is kept out of the sewers, and proper allowance made for yard, street, and roof drainage, there need be no difficulty whatever on this head.

I earnestly recommend sewage farming as applicable to all water-closet towns without exception, and feel sure that it will be far more satisfactory for the kingdom at large, when it is so utilized, than for it to be sent into the Thames, the Mersey, or the Clyde, to the gradual destruction of our waterways, and the removal from our midst of that which will give sinew, muscle, bone, and marrow to a people languishing for such material; and, in consequence of its scarcity at home at this moment, we have to import the material required for its production from the other side of the globe.

THE BERLIN AND PARISIAN SEWAGE FARMS.*

By C. R. Drysdale, M.D.,
Senior Physician, Metropolitan Hospital, London.

Dr. C. R. Drysdale, in this paper, contended that the only rational and satisfactory way of treating the sewage of cities, and restoring the rivers to their original purity, was by the method now used in Berlin, Paris, Croydon, Birmingham, Nottingham, and elsewhere—that is, agricultural utilization on suitable areas and soils. This was the only scientific way, and, moreover, the only method compatible with economy of food supplies. The Metropolitan Board of Works was a glaring instance of want of all plan in this question. For years past that Board, against the advice of Lord Bramwell's Commission, had gone on tormenting the dwellers on the Banks of the Thames by pouring daily 150,000,000 gallons of sewage in dry, and 200,000,000 gallons in wet weather into the river, and were now adding a greater absurdity—namely, the erection of two enormous tanks at Barking and Crossness, where a useless experiment with chemicals was to be made. The tanks were to cost £1,000,000 sterling, and the chemicals, &c., perhaps £100,000 a-year. Dublin, Glasgow, and even Edinburgh, were all nearly as bad. Dublin and Glasgow had rivers which were made a disgrace to civilization by the present municipal authorities, and a horror to citizens and visitors to those cities. The sewage farm at Paris, at the Plain of Gennevilliers, had gradually become a most important experiment since the late engineer, M. Durand Claye, after studying sewage farms in England, abandoned the chemical plans as hopeless, and commenced to experiment with some acres with the fluid sewage. At present 600 hectares, or 1,500 acres, were irrigated with the sewage of Paris, and 20,000,000 of cubic mètres of the sewage were annually used. The prosperity of the Plain of Gennevilliers, which was cultivated by small proprietors, and also its salubrity, had been greatly increased; for in the five years ending 1886, the population of the Plain had increased 34 per cent., and the annual rental of the land increased from 90 to 450 francs per hectare. The Parisian authorities had been so convinced of the success of this experiment that the remaining portion of the Parisian sewage was soon to be utilized on about 3,000 acres at Achères, and there was also to be a further irrigation of the sewage at the east end of Paris. The amount of market produce obtained on the farms at Gennevilliers was quite remarkable—such as 40,000 heads of cabbages per hectare (16,000 per acre), and 100,000 kilos of beet per hectare (40 tons per acre). The peasants raised a gross value of from £120 to £400 per hectare from the land annually. Vegetables of all kinds were grown for the Parisian markets, and in dry seasons a great portion of the supply was obtained on the carefully cultivated market gardens. The contents of a cubic mètre (220 gallons) of the sewage supplied to the farms in 1883 amounted to 0·581 kilos of volatile and combustible matters, and to 1·355 kilos of minerals; together, 1·936 kilos per cubic mètre. The effluent, which was potable, contained 0·156 kilos volatile and combustible, and 0·506 kilos mineral matter per cubic mètre. The irrigation and purification of the sewage went on in winter as in summer. In January 1883, 182,973 cubic mètres were filtered; in May, 2,155628; and so on in summer. The sewage water seldom froze. The chief requisite of sewage irrigation was that the sewage should reach the irrigated fields as quickly as possible in a fresh state, and that the fields should be levelled, so that the water entered not more than 18 inches, and the land should be dry six hours subsequent to each irrigation. Chalk and marly soils were excellent. Each acre of suitable land could utilize 5,000 tons annually; produce 40 tons of mangolds and five or six crops of ryegrass each season,—8 tons to each cutting. The milk of the cows fed on the Paris farms was excellent. The death-rate at the Beddington (Croydon) sewage farm was only 16 per 1,000 per annum, and no parasitic disease was recognised to attack cattle fed on its produce. The Berlin sewage farms employed 2,056 persons, and were a great success. The cities of Berlin, Danzig, and Breslau, with an aggregate of about 2,000,000 inhabitants, had had excellent sewage farms for the last fifteen years. Berlin had now under sewage irrigation 16,657 acres on the north, north-east, and south of the city. The lengths of the conduit pipes used to convey the sewage to these farms from the various districts of Berlin varied from 964 mètres to 18,628 mètres. So perfectly healthy were the farms that convalescent homes had been erected on them. The persons employed on the farms consisted of 40 officials, 45 gardeners, smiths, and dairymen, 480 male and 125 female labourers, 966 workhouse hands, continually employed, and 360 men, women, and children employed from April to October. In one week in October, 1887, 30,000 cwt. of cabbages were sent by rail to Berlin from only one of the farms at Osdorf. In 1885 there were about 275 hectares under root crops, 91 under hemp, 1,625 under wheat and other cereals, 44 of peas and beans, 148 under fodder, 696 under potatoes, cabbages, and the like, 76 in nursery gardens, 1,267 under meadow land and pasture. On 31st March, 1886, the capital borrowed by the sewage irrigation authorities of Berlin appeared to have been £3,211,138, whilst Sir R. Rawlinson had said, at the Society of Arts, in 1887, that the sewage experiment at London would cost ten millions sterling for no purpose, and no benefit to agriculture. The Thames sewage was to be treated with 3·7 grains of lime, 1 of sulphate of iron, and a little permanganate of potash per gallon, whereas towns which had used chemicals had found that nothing short of one ton per million of gallons was of any use. In 1887, Dr. Collingridge, the Medical Officer of the Port of London, said that the condition of the Thames was as bad as ever in spite of the chemicals; and calculating the value of London sewage with a population of about four-and-a-quarter millions, it had been said it should be worth £1,000,000 a-year, and that it might raise fodder enough to feed 200,000 cows annually, and thus give milk to the London children. Mr. Bailey Denton, an engineer of great experience, and Colonel Jones of Wrexham, a sewage farmer himself, had a project to convey the London sewage to an island, Canvey Island,

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* Read in the Section of Public Medicine at the Annual Meeting of the British Medical Association in Glasgow, August, 1888.

20 miles beyond Barking, where it might be partly utilized on 415,000 acres of land: and the pipe might be tapped on the way, and irrigate thousands of suitable acres in Essex, &c. Canvey Island was about 35 miles from London Bridge, and it was calculated that, with a current of three miles an hour, the sewage would reach it in twelve hours. It was to be hoped that Dublin, Glasgow, and Edinburgh—for even in the last named city sewage farming was rudely and only partially carried out—might begin to emulate Berlin, Paris, and other Continental cities, and to purify their rivers and utilize their sewage in the interests of human food supplies and health.

ON THE DISPOSAL OF SEWAGE.*

By Dr. T. J. Dyke,
Medical Officer of Health (Urban and Rural), Merthyr Tydvil.

Dr. T. J. Dyke said, that in 1871 the Local Board of Health of Merthyr Tydvil entrusted to Mr. J. Bailey Denton, C.E., the employment of the best known method of disposing of the sewage from the residences in Merthyr, Dowlais, &c. Mr. Denton advised the adoption of the process of Dr. Edward Frankland, known as the Downward Intermittent Filtration process. A site was chosen at Troedyrhiw, three miles below Merthyr, on the west bank of the Taff River. There, on a gravelly soil, Mr. Denton formed filtration areas on sections of land, by deep drainage, levelling of surface, and provision of an efficient outlet for the effluent water. Each area or section was flooded with strained sewage for six hours, and allowed to rest, to drain, and to be aërated for eighteen hours. The work was completed in the spring of 1881, and from thenceforth from 1 to 300,000 gallons of the strained liquid has daily been passed over and through the soil of the twenty acres of land so prepared. The surveyor, Mr. Harpur, and the superintendent, Mr. Baltram, concur in stating that the work has been carried on without any injury to health; that the land continues to act as perfectly as at the commencement in clarifying the sewage liquid; that the effluent water is perfectly clear and odourless; that there has been no "clogging of the soil, no boginess of the surface;" and that during the years 1886 and 1887 the work of the farm has been carried on at a profit. The Board had, previously to the adoption of Mr. Denton's plan, obtained powers to take land situate nine miles from Merthyr for the disposal of sewage by wide irrigation. In 1872 and following years, the surveyor to the Board laid out 262 acres of land, and adapted the surface for this method of disposing of the sewage. The land was regularly drained, by drains cut three feet deep, the sewage allowed to flow along contour lines over the whole surface. The amount, during the last four years, which was daily so disposed of, amounted to a million and a-quarter gallons. The quantity was the outcome of the excess of sewage not utilized at Troedyrhiw, and the sewage from Merthyr Vale and Treharris, in the valley of the Taff, from Aberdare, Mountain Ash, and Penrhiwceiber in the valley of the Cynon, west of Merthyr. Both the surveyor and superintendent of the farms state that this process is carried on without any detriment to health; and with regard to returns for labour and *matériel*, that a fair profit has resulted. The total population of the several towns and villages connected with these sewage farms would be not less than 100,000. The total estimated dry weather sewage, 1,350,000 gallons daily, was disposed of on 282 acres of land, prepared by either the filtration or the irrigation method. The crops grown on the lands were—ordinary grass, Italian ryegrass, potatoes, cabbages, mangolds, swedes, &c. These vegetable growths were perfectly healthy and sound.

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* Read in the Section of Public Medicine at the Annual Meeting of the British Medical Association in Glasgow, August, 1888.

In the discussion which followed the papers read on the Sewage Question, Dr. Littlejohn gave a description of the disposal of the Edinburgh sewage; and he pointed out both the northern and southern watersheds had been drained into iron pipes and the sewage carried out to sea, while the old town had, for the last 200 years, disposed of its slop water, and ultimately of its sewage, on a sandy waste now well known to sanitarians as the Craigentinny Meadows. This sewage farm was so well managed financially, as frequently to have a revenue of £40 per acre, but at the same time was laid out in a most imperfect manner, and in the hot months became a source of nuisance from the bad odours. Such complaints could easily be removed by a little attention to the manner of disposal of the sewage. These meadows had no injurious effect on the health of the sparse population living amid the meadows, or of the nearest population of Edinburgh. He could not but regret that so much valuable manurial matter was cast into the sea, when the evidence, as given by previous speakers, was so strong, of the advantages to be gained from the direct application of the sewage to the land.

Dr. N. S. Davis (Chicago, U.S.A.) said Chicago had made investigations to carry the sewage of 750,000 inhabitants through canals into the Illinois River, and thence into the Mississippi River. Several years since the city spent 3,000,000 dollars to deepen the Illinois and Michigan Canal, to carry the sewage into Illinois River; but it was found to accomplish the work very imperfectly, while it so contaminated the river water that fish perished, and the inhabitants complained more or less for 100 to 150 miles distant in the central part of the State. Yet at times much of the sewage was washed into the lake, and contaminated the water which forms the drinking supply of the city. In order to get over the difficulty the city had tunnelled for three miles under the lake, to take the water from a part of the lake still uncontaminated. All the inquiries were still being directed to methods of disposal into the rivers and watercourses, which Mr. Davis did not believe safe. The only reliable method, in his opinion, was to return the manurial matters back to the soil. One suburban town, called Pullman, owned by Mr. Pullman, of sleeping-car fame, disposed of its sewage by irrigation. It was carried out three miles before being applied to the soil. This experiment of Mr. Pullman had been quite successful. Dr. Davis advocated, that all the sewage of the large American cities should be disposed of on the available lands to be found within from ten to forty miles of their borders.

Lieut.-Colonel Alfred S. Jones, C.E., expressed his pleasure in hearing the President's paper regarding Edinburgh, as he (Colonel Jones) had been appealing to the Craigentinny Meadows for the last twenty years as the parent of sewage farming. He quoted the case of Wrexham, a town of 12,000 population, which had utilized its sewage, for the last sixteen years, within half-a-mile of the town. He had been tenant of the farm with obligation of purifying the sewage, and gained the £100 prize offered by the Royal Agricultural Society of England for the best managed sewage farm in 1879. All his accounts for seven years were published in the Journal of that Society. Wrexham was now so satisfied with the sanitary results of sixteen years' irrigation at its gates, that it was not afraid to purchase 200 acres two miles lower down the brook which led the effluent into the River Dee, from which the city of Chester takes its water supply. He stated the rent, rates, and taxes over his farm as £5 per acre, whereas, without the sewage, the land ought not to be charged with more than £2 10s., or £3 at most, which would give a satisfactory result on the 16 years' working.

Mr. W. R. W. Smith (Glasgow) said that the disposal of sewage was quite possible, and that that disposal must be arranged by the various Local Authorities either in precipitation or irrigation, and such being so, that all Local Authorities, who had power to bring in clean water, should be compelled to take away the water after being dirtied.

Dr. Bateman (Norwich) said, that of all the questions discussed in that Congress none were more important than the disposal of sewage, and that it was a lamentable fact, that in the broad daylight of the nineteenth century we were still in the dark as to the best means of meeting the difficulty. He then proceeded to give a brief account of the sewage arrangement at Norwich, carried on at an enormous expense, and which had proved a gigantic failure, owing, in a great measure, to hydraulic difficulties. He considered irrigation as the best system, but emphasized the importance of avoiding any possibility of a mistake as to the choice of a site.

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